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Development of Global Land Surface Emissivity Map

Hamidreza Norouzi*, Marouane Temimi, Hosni Ghedira, and Reza Khanbilvardi

The City University of New York, City College, NOAA-CREST, New York, USA
160 Convent Ave, New York, NY 10031
hnorouzi@gc.cuny.edu; temimi@ce.ccny.cuny.edu; ghedira@ccny.cuny.edu; Khanbilvardi@ccny.cuny.edu

Abstract—
Land emissivity is a crucial boundary condition in Numerical Weather Prediction (NWP) models. The objective of this study is to develop global land emissivity maps using AMSR-E passive microwave data. Additional ancillary data will be used to assess the atmospheric contribution and identify clear sky conditions. AMSR-E is the primary source of data in this study. Passive microwave data provided by this sensor are measured at different frequencies varying from 6.9 to 89 GHz. The emissitvity estimation over ocean is more straightforward given the relative simplicity of the background. However, over land, surface conditions affect considerably the radiative transfer process. Thus, ancillary data have been used in this study to assess the land use globally and adjust accordingly the radiative transfer model.

In this study, several satellite based data are used. These data were taken in July 2003 time period because of good temporal coverage of all necessary ancillary of observations. Using MODIS LST products, emissivities for 06.9, 10.7, 18.7, and 36.5 GHz have been retrieved. Also, in order to find the most appropriate skin temperature, ISCCP-DX product has been used over Australia . These maps are very well consistent with previous studies.

Emissivity Calculation

In the AMSR-E microwave frequencies range, for a non scattering plane-parallel atmosphere and, for a given path zenith angle, the brightness temperature (Tb) observed by the satellite instrument can be expressed as

$$Tb_{(p,\vartheta)} = (T_{skin} \times \varepsilon_{(p,\upsilon)} \times \Gamma) + (T_{(\upsilon,\downarrow)} \times (1-\varepsilon_{(p,\upsilon)}) \times \Gamma) + T_{(\upsilon,\uparrow)}$$

$$\Gamma = \exp\left(\frac{-\tau_{(0,H)}}{\cos(\theta_z)}\right)$$

$$T_{(\upsilon,\uparrow)} = \int_0^H T(z)\alpha(z)e^{-\tau(z,H)/\cos(\theta_z)}dz \qquad T_{(\upsilon,\downarrow)} = \int_0^H T(z)\alpha(z)e^{-\tau(0,z)/\cos(\theta_z)}dz$$

$T_{b(p,\upsilon)}$ and $\varepsilon_{(p,\upsilon)}$ are the instrument Tb and the surface emissivity at frequency and for polarization *p*, respectively.

T_{skin} , $T_{(\upsilon,\downarrow)}$ and $T_{(\upsilon,\uparrow)}$ are the skin temperature, the upwelling and the downwelling Tbs respectively. is the net atmospheric transmissivity. So, we can say (Prigent et al. 1997):

$$\varepsilon_{(p,\vartheta)} = \frac{(Tb_{(p,\upsilon)} - T_{(\upsilon,\uparrow)} - T_{(\upsilon,\downarrow)} \times \Gamma)}{((T_{skin} - T_{(\upsilon,\downarrow)}) \times \Gamma)}$$

Atmospheric correction

Simple equations have been proposed by different scientists. For example, Choudhury has proposed a linear regressions which were written as (Choudhury 1993):

$\tau = 0.011 + 0.0026V$ for 19.3GHz
$\tau = 0.037 + 0.0021V$ for 37GHz

Where, V is the total perceptible water vapor within atmosphere in mm.
And, it can be verified for an isothermal atmosphere that:

$$T_{\uparrow} = T_{\downarrow} = T_e(1-\Gamma)$$

Where, Te is the isothermal air temperature [i.e.$T(z) = Te$].
And using observed upper air sounding data, it would be:

$T_e = T_a - (8 + 0.06V)$ for 19.3GHz
$T_e = T_a - (18 - 0.12V)$ for 37GHz

Which, Ta is the air temperature.

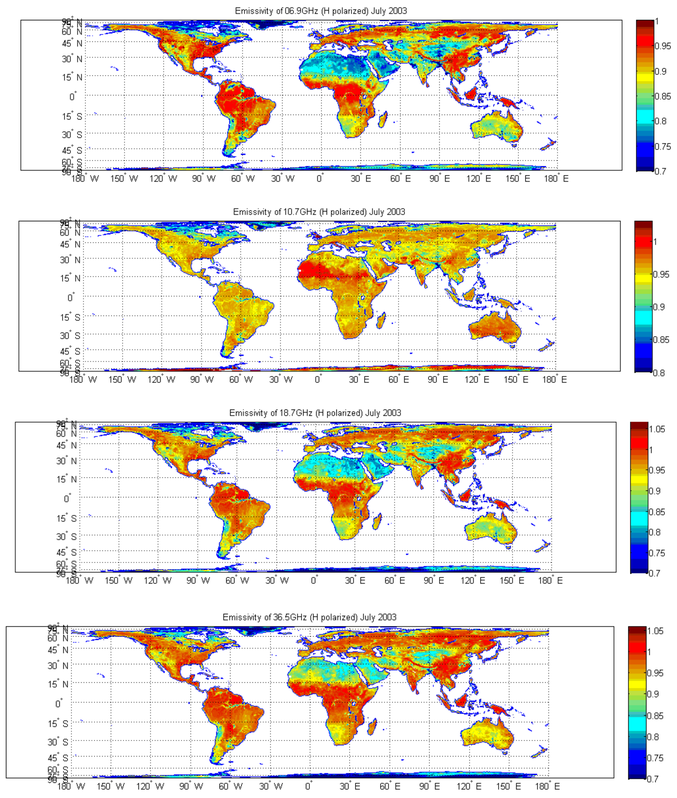

Figure 1: Composite monthly average (July 2003) retrieved emissivity from AMSR-E using MODIS data for skin temperature for 06.9, 10.7, 18.7 and 36.5 GHZ at both H polarization in global scale.

Datasets:

The main microwave sensor in this project is AMSR-E, Level-3 land surface product (AE_Land3) which is resampled to a global cylindrical 25 km Equal-Area Scalable Earth Grid (EASE-Grid) cell spacing was used. For the skin temperature, there are two Infrared based data. The First one is ISCCP data. In the ISCCP data, cloud parameters and the related quantities are retrieved from visible (VIS) and infrared (IR) radiances provided by set of polar and geostationary meteorological satellites (Rossow and Schiffer, 1991). The pixel level data set (the DX data set) is used for its resolution of about 30 km and its sampling interval of 3 hours.

The other available data set is MODIS LST product. In this project, MODIS11C1 was used which is a daily global LST product. It provides temperature and emissivity values at 0.05 degree latitude/longitude climate model grids (CMG). In this data set, cloudy pixels are highlighted in the quality flag values. It also has the same equator crossing time with AMSR-E, since both of them are boarded on Aqua satellite. Therefore, it also provides two measurements per day. In this project, both type of data (ISCCP and MODIS) has been tried in order to find more appropriate data set for retrieving the land surface emissivity.

For calculating atmospheric parameters in general formula, TIROS Operational Vertical Sounder (TOVS) data set was tried which has been gridded by ISCCP (Rossow et al, 1996). The ISCCP TOVS data set has a spatial resolution of approximately 2.5 degree in latitude and longitude.

Results

Using methodology described, retrieving the emissivity according to the general formula has been tried. In this step, retrieving the emissivities has accomplished for July 2003 by AMSR-E level 3 data and MODIS LST for skin temperature and cloud mask with the same project with AMSR-E data.

The microwave land surface emissivities retrieved for 06.9, 10.7, 18.7 and 36.5 GHz (both V and H polarized) which are close to simple equations were proposed, regarding frequencies or for 06.9 and 10.7 GHZ has assumed the atmospheric effect in negligible. These very recent results are in global scale (figure 1. There are less than 4% of the pixels have the emissivity more than 1 which physically has no meaning. Investigation of the reasons is studying these days.

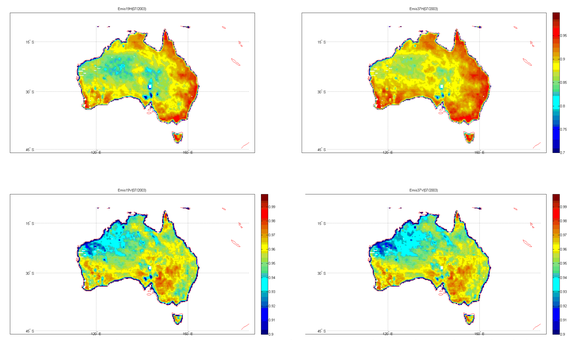

Figure 2: Composite monthly average (July 2003) retrieved emissivity from AMSR-E using ISCCP data for skin temperature for 18.7 and 36.5 GHZ at both Hand V polarizations over Australia.

Moreover, in order to find the most appropriate skin temperature, ISCCP-DX product has been used over Australia which will be extended to whole of the globe (figure 2). These maps are very well consistent with Prigent's (Prigent et al. 1998) and AER's (Galantowicz et al. 2006) products qualitatively, and quantitatively verification is still in process (figure 3).

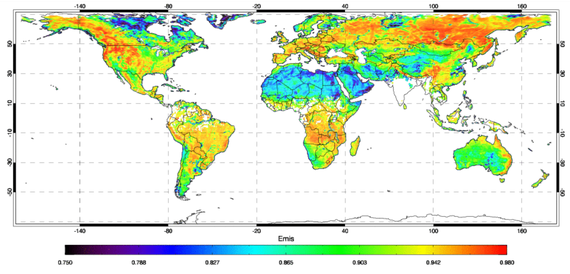

Figure 3: AMSR-E 19H nighttime emissivity retrieved with baseline processing, July 2003 average (Galantowicz et al. 2006) .

Future works:

-Quantitatively validation of model using previous studies.
-Extending the ISCCP based emissivity map to global.
- Studying the effect of snow and topography.
- Investigating the potential of extrapolating AMSR-E emissivity to L band frequency.
- Investigating the potential of extrapolating AMSR-E emissivity to AMSU sounding channel frequencies.